Application No. 09/821,410
Amndt.dated: January 4, 2005
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Amendments to the Specification:

Please replace paragraph [0014] beginning at page 5, line 13, with the following rewritten paragraph:

- -**[0014]** Embodiments of the present invention also include generating a training signal sequence and transmitting the training signal sequence over a transmission media channel to generate an observed or measured output signal. ~~, convolving the training sequence with an unknown impulse response representation of the transmission media channel to form a computed output signal of the channel, and minimizing a~~ A minimized difference value between ~~an~~ the observed or measured output signal of the channel and a signal value representation of convolution of the training signal sequence and the unknown impulse response of the channel, together with ~~the computed output signal of the channel. The method also includes using the minimized difference,~~ the training signal sequence, and the observed or measured output signal to compute an initial impulse response of the channel. Further refinements or fine-tuning of the impulse response then can be done using other known convergence techniques.- -

Please replace paragraph **[0019]** beginning at page 7, line 13, with the following rewritten paragraph:

[0019] In accordance with an embodiment of the invention, a correlation based technique for rapidly identifying (i.e., estimating or determining) the impulse response of a transmission media channel is provided. The identification is used for rapid initial training of an echo canceller and a channel equalizer after which other known techniques can be used for further training, as will be described below. The technique of the present invention works as follows. Assume a known time domain sequence

$$x = [x_0, x_1, \cdots, x_{T-1}]$$

is an input to a transmission media channel 10 as a training sequence, as shown in Fig. 1. The sequence can be a series of wide-band pseudo-random time domain signals of length T, as will be appreciated by those skilled in the art. The transmission channel 10 in Fig. 1 has

an unknown impulse response h(n), for n=0 to N-1, and y(k) is the observed or measured output for k=0 to T-(N+1), where N is the number of coefficients of the impulse response h to be determined. Then, the output of the transmission channel 10 can be expressed as

$$y_k = \sum_{n=0}^{N-1} h_n x_{k+n} + g_k \quad , \tag{1}$$

where g_k is a signal noise component. Mathematically, Equation (1) is the convolution of the transmission channel's unknown impulse response h and the known input sequence x. Equation (1) can also be represented in matrix notation as

$$Y = XH + G \quad , \tag{2}$$

where X is a matrix with elements

$$X_{[k][n]} = X_{k+n}$$

For certain applications, it is reasonable to neglect the noise component because its effects are not as severe as the channel impairments on the received signal. Doing so and letting E be the squared error vector of the difference between the actually observed or measured channel output Y (which is a function of the actual *h* and *x)*, and ~~the computed~~ <u>an</u> output <u>signal value representation</u> *XH*, the error vector *E* can be expressed as

$$\begin{aligned} E &= |Y - XH|^2 \\ &= (Y - XH)\left(\overline{Y - XH}\right) \\ &= Y\overline{Y} - Y\left(\overline{XH}\right) - (XH)\overline{Y} + (XH)\left(\overline{XH}\right) \\ &= Y\overline{Y} + \overline{H}\,\overline{X}XH - \overline{Y}(XH) - \left(\overline{H}\,\overline{X}\right)Y \quad , \end{aligned} \tag{4}$$

where the "bar" over a term indicates the Hermetian of that matrix or vector. To minimize the squared error, the partial derivative of the error vector *E* with respect to *H* is equated with zero, as

$$\frac{\partial E}{\partial h_n} = 2\overline{X}XH - 2\overline{X}Y = 0 \tag{5}$$

Equation (5) can be rearranged as

$$2\overline{X}XH = 2\overline{X}Y$$

or

$$H = \left(\overline{X}X\right)^{-1}\overline{X}Y \quad ,$$

where

$$\left(\overline{X}X\right)^{-1}$$

is a square symmetric matrix. Setting

$$M = \left(\overline{X}X\right)^{-1}\overline{X} \tag{6}$$

gives

$$H = MY \quad . \tag{7}$$

Thus, the impulse response of the transmission media channel can be expressed as a product of the matrix *M*, which depends solely on the known input training sequence *X*, and the observed or measured output vector *Y*. In other words, the matrix *M* operates on the vector *Y* to give the channel's impulse response. As will be appreciated by those skilled in the art, if the length of the input sequence x is T and the length of the channel impulse response is N (i.e., N is the number of coefficients needed to span the length of the channel's impulse response), then *M* is a (T-N) x N matrix and $\left(\overline{X}X\right)^{-1}$ is an N x N square symmetric matrix.